COST-EFFECTIVE INFRASTRUCTURE AND WATER SUPPLY DESIGN OF HILLY TERRAIN (AKBAR TOWN ATTOCK)

Submitted By

RAMSHA SHOAIB (G.L) **(284136)**

HAJIRA SHAH **(303560)**

Project Advisor

Dr. Abdul Waheed

Project Co-advisor

Lec Ameer Hamza

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology, Islamabad, Pakistan

CERTIFICATION

This is to certify that the thesis entitled.

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Submitted by

RAMSHA SHOAIB **(245628)**

HAJIRA SHAH **(303560)**

Has been accepted towards the requirements.

For the undergraduate degree in **Civil Engineering**

Dr. Abdul Waheed (Associate Professor)

NUST Institute of Civil Engineering (NICE)

National University of Sciences and Technology, Islamabad, Pakistan

DECLARATION

We hereby declare that the thesis entitled “the cost-effective infrastructure and water supply design of Akbar town Attock**,**” submitted by us, is based on the study and work done solely by us. All references to work done by any other person, institution, or source have been duly cited. We further clarify that this thesis has not been published or submitted for publication anywhere else.

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In the name of Allah, the most merciful, the most compassionate, all praises be to Allah, the lord of the worlds, and prayers and peace be upon Muhammad (S.A.W), his servant and messenger. Completing this project was possible only because of the blessings of Allah Almighty and the collaboration of many people to whom we are sincerely grateful. We would like to thank our parents for their love and support and all the people that supported us during this project. We would also like to pay a debt of gratitude to our advisor, Dr. Abdul Waheed, for the profound encouragement, support, and valuable time he provided for this work. He motivated us during the whole project and encouraged us in what we were doing. He provided us with guidance for countless hours; without him, this thesis would not have been written.

Abstract

Urban infrastructure plays a vital role in the development of urbanization of any city. And optimized infrastructure is very important for sustainable and smart cities development urban designing depends upon the type of master plan. master plan basically includes the type of road and street pattern which have been used. The saleable area depends upon these two above factors. So, it is very important to select the appropriate patterns for efficiency and cost effectiveness. All the infrastructure depends upon these two. which have been followed. the master plan includes the road and street pattern which have been followed. The road pattern is a crucial component of urban infrastructure development, as it affects the connectivity, traffic flow, economic growth, safety, and sustainability of a city. A well-planned road network can connect different parts of a city, improve accessibility, reduce congestion, minimize travel time, attract investment, promote sustainable transportation, and enhance safety for motorists and pedestrians. Additionally, it can provide safe spaces for pedestrians and cyclists, making the city more livable and promoting healthy lifestyles. Therefore, careful consideration of road pattern design is essential for successful urban infrastructure development. Infrastructure design plays a crucial role in the development of urban areas. It involves planning, designing, and constructing physical structures and systems that support the needs of the community. The design of infrastructure includes roads, bridges, water supply systems, sewage systems, waste management systems, public transportation systems, and more the importance of infrastructure design for urban development lies in its ability to provide the necessary facilities and services that enhance the quality of life for people in urban areas. A well-designed infrastructure system can improve access to essential services, such as healthcare and education, and promote economic growth by facilitating the movement of goods and people.

Infrastructure design also plays a critical role in promoting sustainability in urban areas.

Sustainable infrastructure design includes the use of renewable energy sources, reducing carbon emissions, and implementing green infrastructure practices to promote environmental protection. In conclusion, infrastructure design is a vital aspect of urban development as it impacts the quality of life, economic growth, and sustainability of urban areas. Therefore, careful consideration of infrastructure design is necessary to ensure that the needs of the community are met, and the urban environment is sustainable for future generations. The water distribution is a part of infrastructure development.

Water distribution system (WDS) aims to distribute water from reservoirs or aqueducts to the end-users. This system is part of the water supply network that carries potable water from a central treatment plant or wells to water consumers in order to deliver water sufficiently to meet residential, commercial, industrial, and firefighting requirements. Modern systems aim to solve water distribution systems management problems, such as the lowest cost, and most efficient design by using linear/nonlinear optimization schemes, which are limited by the system size, the number of constraints, and the number of loading conditions. After a literature review for the articles that dealt with this topic, designing two parts of the water distribution system is discussed as a case study in Erbil. Pumps and storage tanks, while optimizing the water distribution system by minimizing the project cost through minimizing the volume of the elevated tank according to the pump working hours.

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Chapter one

Introduction

1.1 General

Attock is a city in northern Punjab, Pakistan, located about 80 kilometers from the capital city of Islamabad. It is known for its strategic location at the entrance to the Khyber Pass and has a population of approximately 300,000 people. Akbar Town is a newly built society in Attock, which is a residential area that has been developed to provide housing for the growing population. It is named after Akbar Khan, a former governor of the province.

Street patterns are an especially vital component of pro urban planning. Major cities always go for a unique and efficient street pattern because all the economic and social activities are dependent on traffic movements. The more efficient the street pattern is, the more economically efficient the city is, as it will reduce the travel time and distance. Which also reduces the emissions of harmful gases from automobiles into the atmosphere.

Street patterns determine the amount of development that can be accommodated, its form, its density, and its relationship to the street itself. The street pattern also forms the foundation of the transportation system and affects all aspects of its function. It impacts the circulation of automotive traffic, its speed, and its congestion. It also provides the framework in which public transit must operate, the network that cyclists can navigate, and the connectivity that pedestrians experience. With all modes, the street network can affect the user's experience, the mode's potential utility, and the interactions between modes. Since the beginning of civilization, providing access to clean water and sanitary facilities has been a logistical difficulty.

The history of water supply and sanitation is one of a logistical challenge to provide clean water and sanitation systems since the dawn of civilization. Early human settlements were frequently constructed close to water sources. Rivers were frequently used as a rudimentary method of sewage disposal. The lengths that water can be transported across have greatly grown thanks to technology over the centuries. Additionally, methods for treating wastewater and drinking water have been improved. The earliest permanent water wells, from which containers could be filled and carried by hand, were excavated by humans during the Neolithic era. In the Jezreel Valley, wells from circa 6500 BC have been discovered. Human settlement growth was greatly influenced by the availability of water in the area.

A primitive indoor, tree bark lined, two-channel, stone, fresh and wastewater system appears to have featured in the houses of Skara Brae, and the Barnhouse Settlement, from around 3000 BCE, along with a cell-like enclave in a number of houses, of Skara Brae, that it has been suggested may have functioned as an early indoor latrine. Effective planning is essential for water and wastewater systems to manage their operations and infrastructure and ensure the sustainability of the communities they serve. (Sustainable Water Infrastructure, 2022)

Benefits from considering sustainability during infrastructure planning include:

- Optimizing environmental, economic, and social benefits by setting goals and selecting projects through a transparent and inclusive process with the community,

- Realizing consistency across a range of alternatives that address both utility and community goals; and
- Enhancing the long-term technical, financial, and managerial capacity of the utility. (Sustainable Water Infrastructure, 2022)

Urban infrastructure planning based on water supply ensures that water infrastructure investments are cost effective over their life cycle, resource efficient, and support other relevant community sustainability goals. (Sustainable Water Infrastructure, 2022). In planning the water supply infrastructure generally two planning horizons are considered:

- For 10 years
- For 20 years
- The good design and construction of groundwater supplies is critical to the prevention of contamination.
- The good design and construction of groundwater supplies is critical to the prevention of contamination.

The good design and construction of groundwater supplies is critical to the prevention of contamination of the water which is the basic criteria for the water supply infrastructure planning. Purity of water is the major concern while planning the water supply infrastructure because of which water supply infrastructure (pipes carrying the water) is currently being placed below the ground surface.

Planners must switch from a predict-then-act strategy to a learn-then-adjust strategy in order to implement adaptive management (Pahl-Wostl 2007). Flexible infrastructure design is a related tactic that enables planners to react to upcoming uncertainty. Additionally, new techniques for planning new infrastructure that are resilient to significant uncertainties like climate change have been created recently. (Fletcher.M. S, et al., 2017) Latin hypercube sampling generates many possible future scenarios across multiple uncertainties, assumes equal likelihood of each scenario, and selects strategies that meet threshold performance criteria across a large percentage of

scenarios (Lempert et al. 2006; Lempert and Groves 2010 Contrarily, info-gap theory creates progressively larger multidimensional uncertainty sets and discovers the solutions that satisfy each uncertainty set's threshold performance criteria (Ben-Haim 2001). A paradigm for modelling water resources that considers the complete spectrum of uncertainty planners confront should incorporate climate change and other significant uncertainties. During the water supply planning, capital cost and operating cost should be kept as low as possible. (Fletcher.M. S, et al., 2017).

1.2 Problem Statement

The road and street pattern basically affects the cost of our infrastructure so to reduce it, an efficient and suitable type of road pattern is necessary . so, in the real time application the Akbar town Attock has a road pattern which has a high cost of water scheme and infrastructure design, so there is a need to design other alternatives which have less cost as compare to original one.

1.3 Objectives

The main objective of this research is to create a road pattern which should have a less cost and more saleable area. The research creates improvements for the selection of road network for any site. This is done so by creating two alternatives for an existing design of Akbar town, and after that their cost have been compared. Basically, it integrates the concept of road type with infrastructure design for any society to filter out the cost effective and efficient road pattern. So, consequently the research also studies a major topic about the cities and their types, the road and street pattern and basic infrastructure utilities.

Another goal is to create a road pattern that is compatible with all kinds of infrastructures. The milestones set to achieve the goals are to recreate the road pattern by keeping all other areas and utilities constant and then compare all road patterns with each other for efficiency and cost effectiveness. The water system for each type of road has also been created and the cost is calculated. In the end the results are compared.

1.4 Organization of the Report

The thesis begins with Chapter 1 discussing the major concept of different street patterns forming the societies proposed in the study, the objectives of the study and the overview of the thesis. Chapter 2 builds upon the general outline of the thesis, giving a deeper insight into the literature review conducted to support the thesis giving a deeper insight into the literature review conducted to support the thesis. Moving to Chapter 3, the thesis explains the materials and methodology used in the research, detailing the mathematical, computational, and experimental model and testing. The results of all three sets of Master Plans are addressed in Chapter 4, and the reasonings behind the specific outcomes are also highlighted. Chapter 5 concludes the entire research and outlines the key points of the work.

Chapter Two

Literature Review

2.1 Importance of Street Patterns for a City

Street patterns are an especially vital component of pro urban planning. Major cities always go for a unique and efficient street pattern because all the economic and social activities are dependent on traffic movements. The more efficient the street pattern is, the more economically efficient the city is, as it will reduce the travel time and distance. Which also reduces the emissions of harmful gases from automobiles into the atmosphere.

Street patterns determine the amount of development that can be accommodated, its form, its density, and its relationship to the street itself. The street pattern also forms the foundation of the transportation system and affects all aspects of its function. It impacts the circulation of automotive traffic, its speed, and its congestion. It also provides the framework in which public transit must operate, the network that cyclists can navigate, and the connectivity that pedestrians experience. With all modes, the street network can affect the user's experience, the mode's potential utility, and the interactions between modes.

2.2 Common roads and street Patterns in the World

Some of the common road patterns existing in the world are degenerate grid, irregular grid, gridiron, broken grid, organic, dead ends, loose grid, dendritic, radial grid, circuitous, suburban, disconnected, fragmented parallel, orthogonal grid, mixed parallel and warped parallel. In a grid iron city layout, streets cross each other at right angles to create a grid-like pattern. ("What Is Road Pattern | Different Types of Road Patterns | Grid Pattern ...") While in dead ends the streets have only one inlet or outlet. The *pattern that* comprises curvy *streets* in long, narrow blocks. T

intersections and L corners are called warped parallel pattern. (Rifaat et al., 2012)

2.2.1 Gridiron Pattern

The Gridiron Street Pattern has many benefits such as it increases accessibility and connectivity between different areas, and it is walkable, navigable and adaptable. “With the proper block size, the grid provides an inherently walkable street network." (“Why the grid is a great asset to our cities | Smart Cities Dive”) With blocks and lots, a new land use can simply be plug-in to the existing infrastructure. Because of the grid plan's many junctions and the direct routes it provides for walkers, some local car trips may be replaced by biking or walking. But, if cars are also allowed on those streets, it makes the same routes more direct for cars, which could be an enticement for driving. Pollutant emissions would be reduced as a result of the anticipated car trip substitution. However, due to its propensity to slow down traffic, the benefit of intersection density for walkers can also work against cars Although the coefficient after levelling off tends to climb progressively beyond 50 mph (80 km/h), low speeds below 20 mph (32 km/h) have a much larger coefficient of pollutant production than above 30 mph (48 km/h). High traffic congestion in regions with commercial usage, where speeds slow to a crawl, accentuates this effect. Since the grid plan is non-hierarchical and intersections are frequent, all streets can be subject to this potential reduction of average speeds, leading to a high production of pollutants." (“Grid plan - Wikipedia”) Greenhouse and noxious gases can be detrimental to the environment and to resident health. But the increased number of intersections reduces the speed of the vehicles thus causing pollution and causes more accidents to occur. The high intersection density in the area also makes it unsecure. Gridiron street pattern also requires more land and is thus less cost effective. But as this street pattern was widely used in historic times, the cities in USA, Canada, Italy, Switzerland, Germany, Australia, New Zealand, Egypt, Japan, China, Pakistan, India, UAE, and Singapore etc. have

gridiron street pattern. In Pakistan, Gridiron pattern existed since around 2600 B.C. during the time of Harappa and Mohenjo-Daro Civilizations. In Greece and Rome, it exists since 5th and 6th century B.C. In Japan, the first gridiron pattern was developed in 7th century B.C.

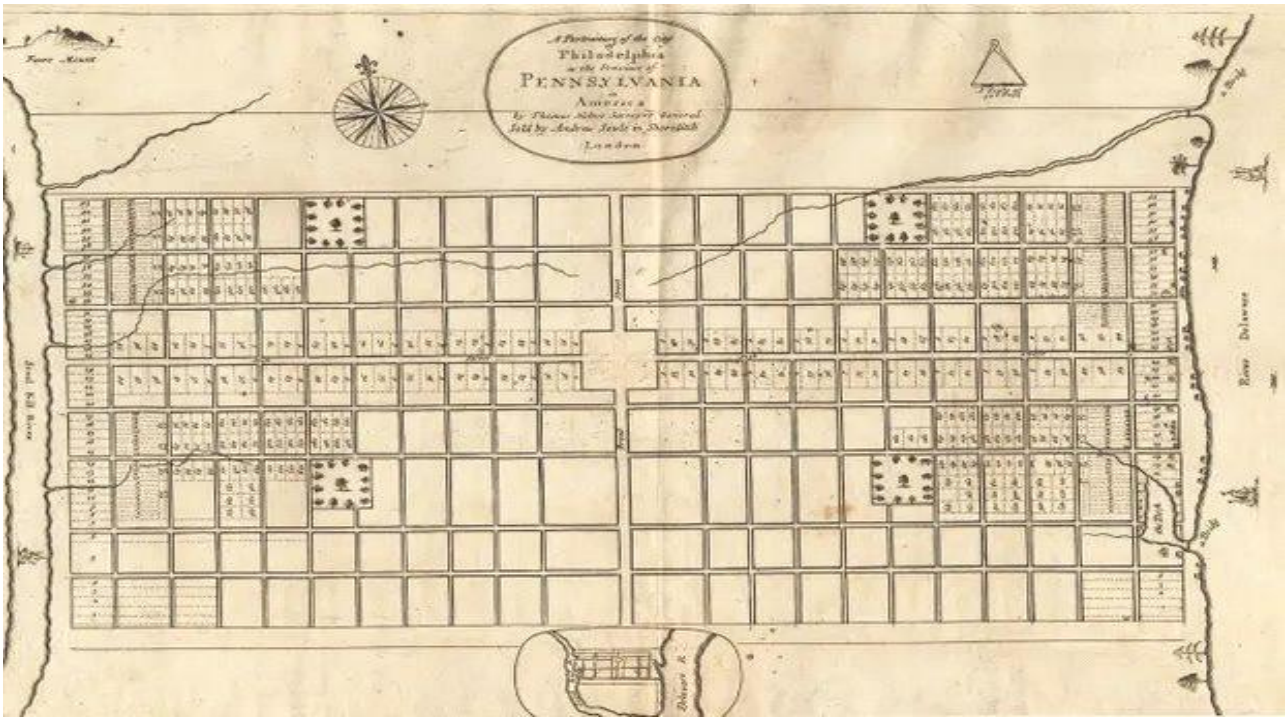


Figure 1 Philadelphia - flat city except for the northwestern area
(Source: Mann, E, 2016)

Figure 2. Chandigarh City – India

(Source: The Indian express, 2021)

2.2.2 Curvilinear Grid Pattern

The Curvilinear Grid Pattern easily adapts to the terrain, but its use is generally confined to the relatively smaller areas. This pattern creates visual interest and provides good architectural settings particularly for residential buildings. This street pattern is difficult to design and layout, more difficult for people to orient to, and difficult to house number. Post 1960 suburbs in Calgary show curvilinear streets. The plan of Old Washington also shows curvilinear street patterns.

Figure 3. Image of suburbs of Calgary on either side of Fish Creek Park with curved street patter. (Source: everyday tourist, 2021)

2.2.3 Spider Web Pattern

Spider Web Pattern creates formalized central space. Traffic is dispersed evenly through the network. Diagonal streets can create hierarchy for through traffic. Although the coefficient after levelling off tends to climb progressively beyond 50 mph (80 km/h), low speeds below 20 mph (32 km/h) have a much larger coefficient of pollutant production than above 30 mph (48 km/h).[38] High traffic congestion in regions with commercial usage, where speeds slow to a crawl, accentuates this effect. This pattern tends to be disoriented. The older part of London which was destroyed in fire had a spider web street pattern in its new map. Old Plan for Washington also shows spider web street pattern.

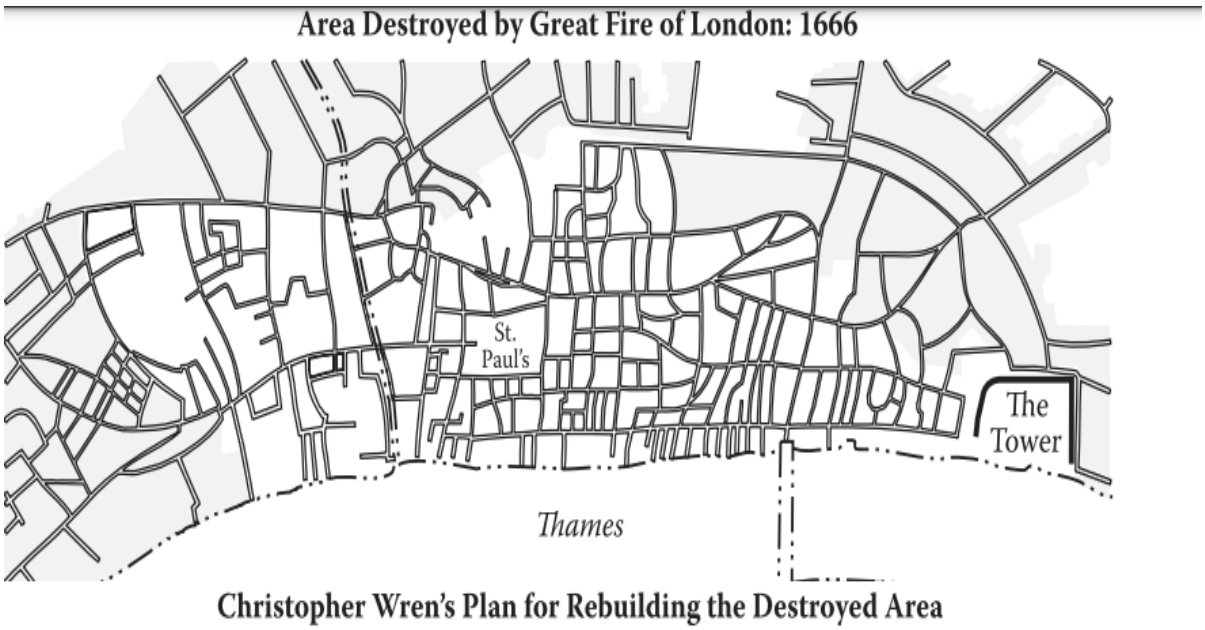


Figure 4. Christopher Wren's plan for rebuilding the destroyed area of London.

(Source: Forrest, A, 2016)

Figure 5. Plan for Washington D.C. 1791

(Source: Columbia historical society, 1899)

Table 1: Type of street pattern of major cities

City	Radial	Deformed grid pattern	Grid iron pattern
Paris	(✓)		
London		(✓)	
New York			(✓)

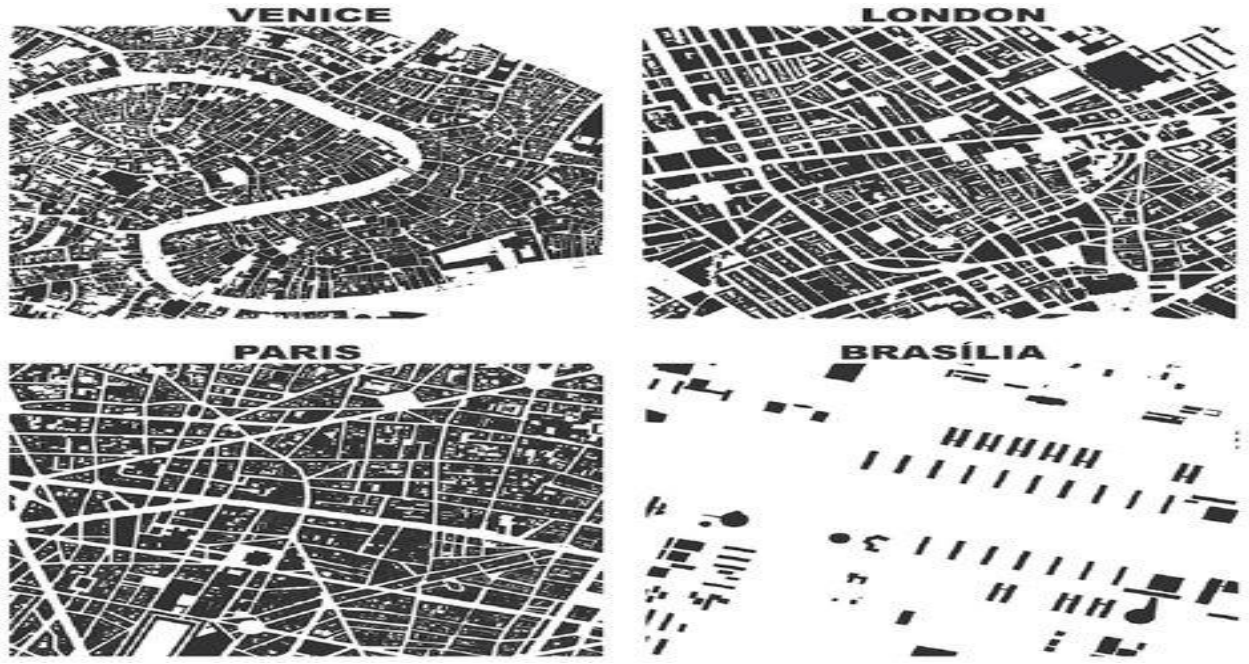
Table 2: Comparison between different street pattern

Comparison between different street patterns			
	Gridiron pattern	Curvilinear pattern	Spiderweb pattern
Economical	X	✓	X
Environment Friendly	X	X	✓
Transportation accessibility	✓	✓	X
Easy to design	✓	X	✓

2.3 Most Efficient Street Pattern

The comparison provides us a knowledge of the efficiency and economical scale of each pattern.by comparing the efficiency and economy of each pattern, it is concluded that the curvilinear pattern is more economical (in terms of place and price) and efficient than others. By consuming a little space, it provide more efficiency. It can be used in almost every case. The traffic congestion issues can be solved by it. Its construction is also not costly. The space consumption is also very less. It is the most emerging pattern in the world. The modified curvilinear grid plan offers fewer connections than the rectilinear and diamond grids and more readily conforms to the topography. ("6. Street Patterns.pdf - Urban Street Pattern ARCH 305:"). The curved street layout is only used in relatively small locations. It is applicable to both fresh and established development patterns. It

is possible to accommodate and design a variety of lots. It is easily adapted to a location's topography, minimizing grading and promoting efficient drainage. Curving roadways can offer



another opportunity to add visual interest because some people find them to be visually pleasant. creating attractive architectural environments, especially for residential structures. Additionally, it stops traffic from transferring from arterials to collector and land access routes.

2.4 Older cities road and street pattern

Mostly the old cities have a diamond, rectangular and rectilinear pattern. (Ameris. (2011). Barcelona: Urban planning's forgotten birthplace). The old London which is now called the northwest of London has a diamond street pattern. (Carlis. K.2019.maptime Amsterdam #5). The new parts of London have mostly curvilinear and stem patterns**.**

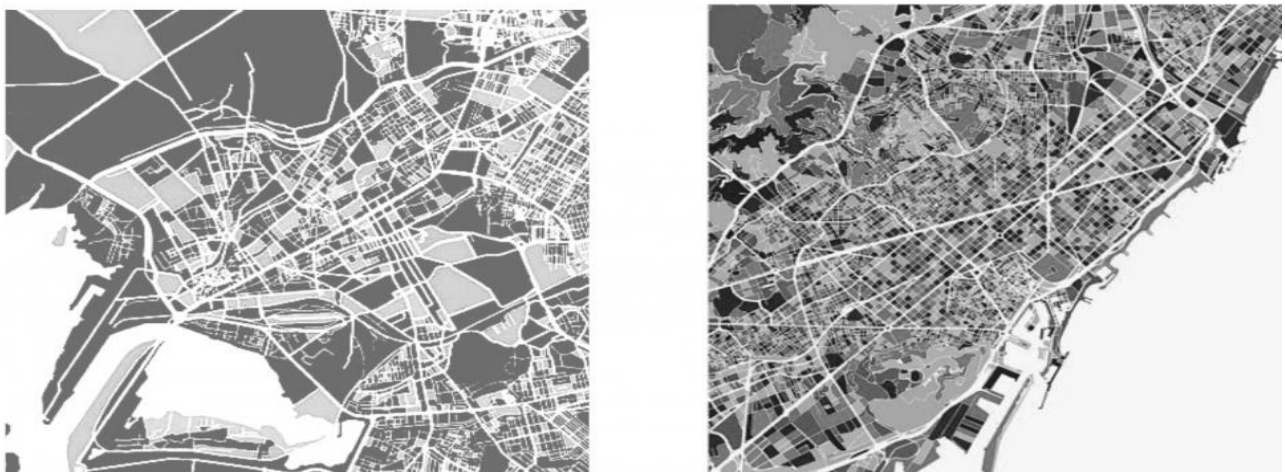


Figure 7 (Boeing.G.2017. Square-Mile Street Network Visualization)

Dubai has a web pattern. And in some parts the radial pattern. (Boeing.G.2017. Square-Mile Street Network Visualization). New Delhi has a radial pattern. (Garimo.2015. Delhi streets pattern).

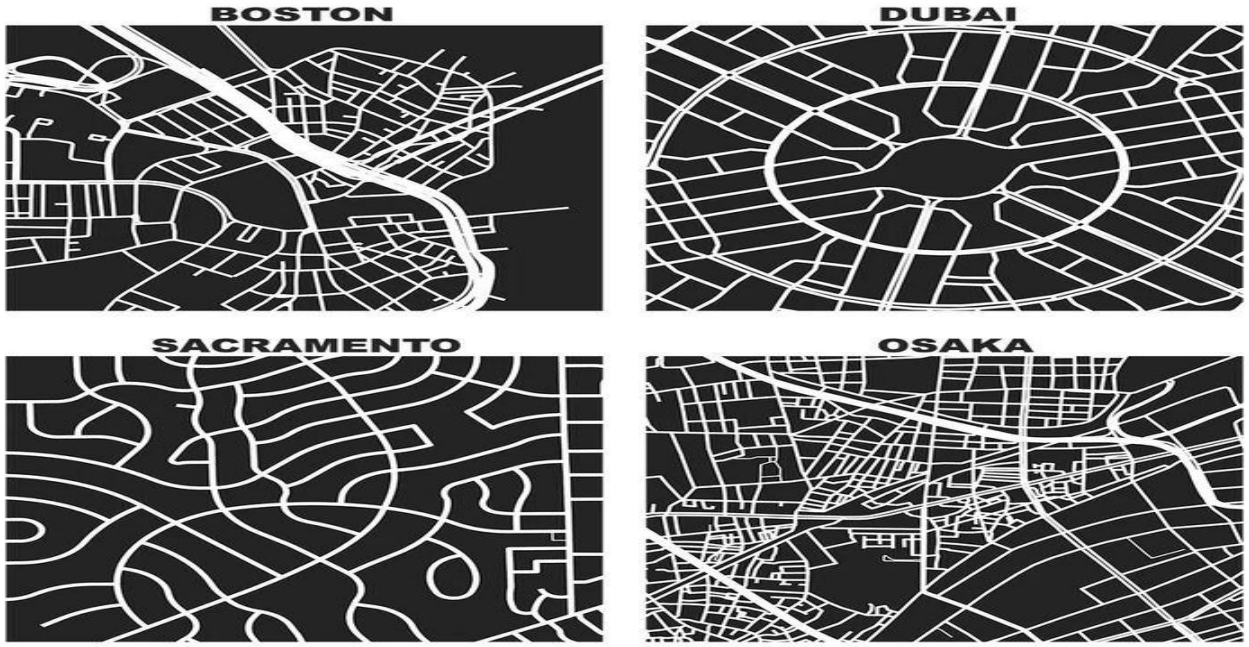


Figure 8 (Marshall.C.2020. For Los Angeles' Future, See Tokyo's Present)

2.5 Old parts and the new parts of cities' street pattern

Some cities even have different street patterns inside them. The different parts of one city have different type of street pattern. This is also due to their era of development. Topography and soil condition. Lahore has different types of street patterns inside it. The old Lahore mainly comprises of diamond and rectilinear pattern. The new Lahore is mostly curvilinear and rectangular depending upon their topography. (Rashid.A.M.2020. Major Road Network of Lahore.) Quetta also has different types of street patterns inside it. The old Quetta has a diamond and rectangular pattern. But the newly developed streets have stem and curvilinear shape. (Alamy.2021.new era of development)

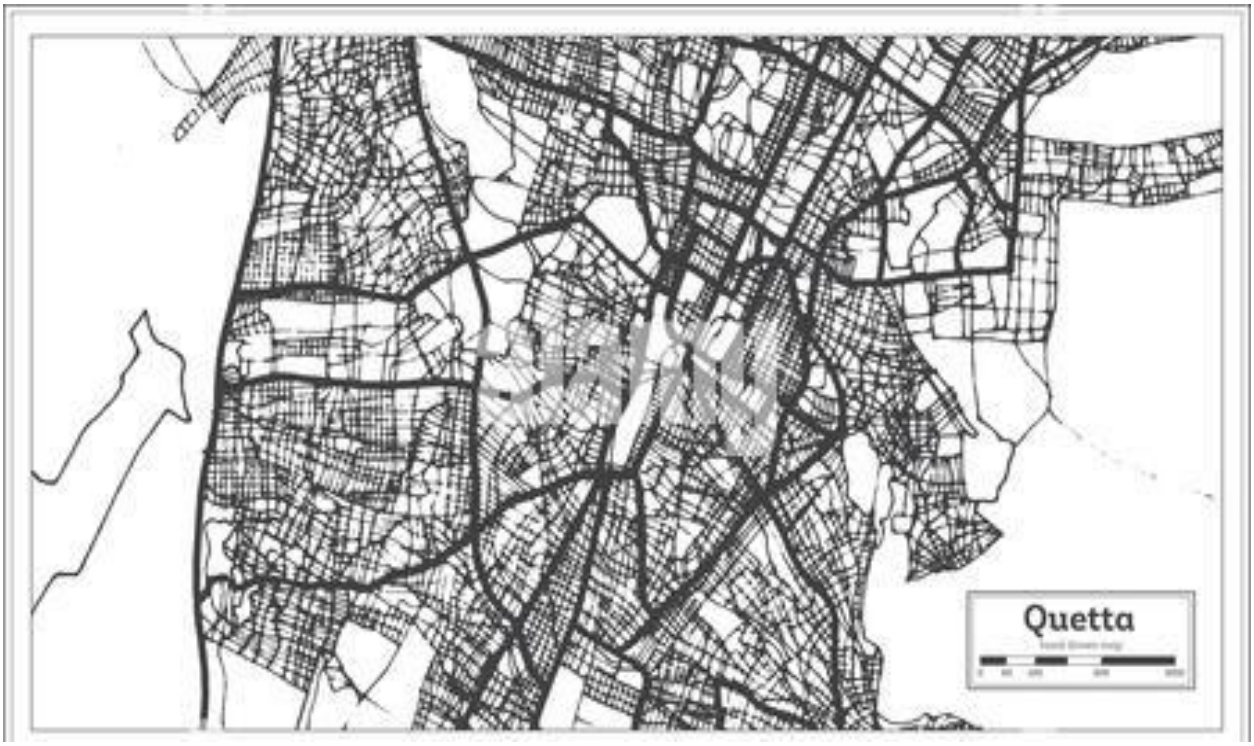
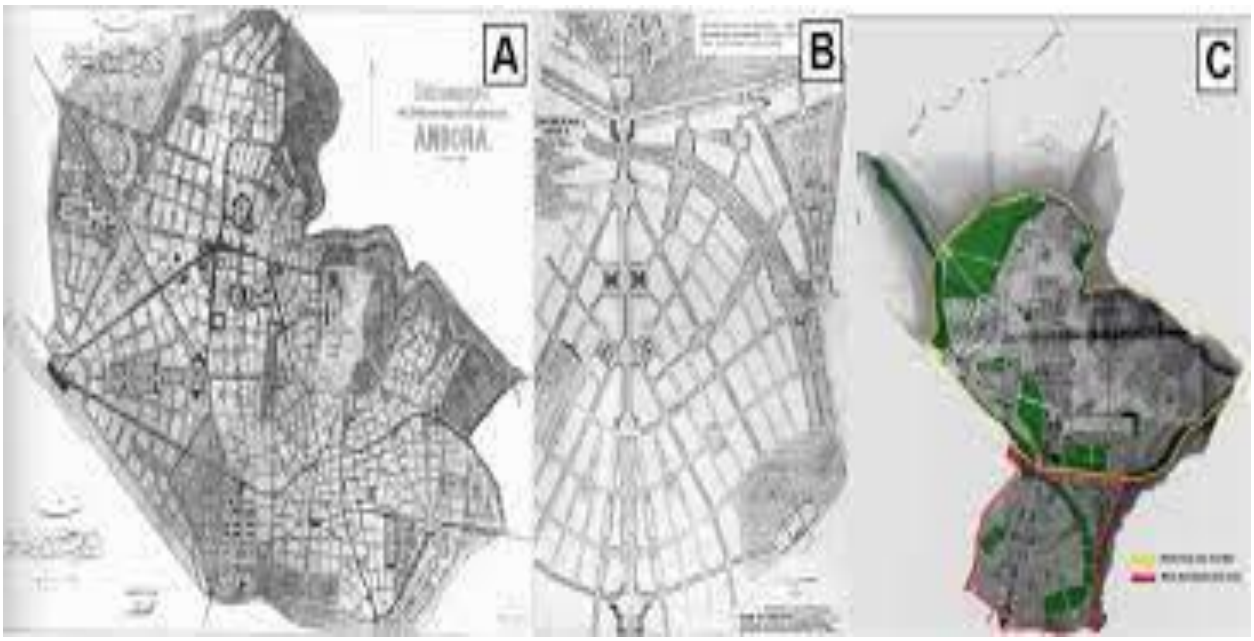


Figure 9: Urban vector city map of Quetta, Pakistan.2018
Figure 10: .Ankara Turkey Map in retro style
Source: (Sorokin)

Ankara has different types of street patterns inside it. The old Ankara mainly comprises of a radial



and rectangular pattern. The newly developed street of Ankara is mostly web and curvilinear depending upon their topography. (Sorokin.I.2017.Ankara Turkey Map in retro style) The A part shows 1920 to 1950 era. The B part shows 1951 to 2000 era. The C part shows the era of 2000 to till now. City of Iran Khorramabad has also different central and surrounding street patterns. (KARIMI.K.2002. Iranian Organic Cities Demystified: A Unique Urban Experience or an Organic City like Others) ("Iranian Organic Cities Demystified: A Unique Urban Experience or an .)

2.6 Comparison between the old and new street patterns and their issues.

2.6.1 Lahore

The growing population needs more space. But the older pattern was so narrow and could not accommodate more vehicles and parking space. Also, there were pollution issues in older street patterns due to less space. Traffic congestion was also the big problem, so new patterns was adopted which are somehow expensive but has solve these issues. (Rashid.A.M.2020. Major Road Network of Lahore.)

2.6.2 Quetta

The migrants from the far areas of Baluchistan were coming to Quetta for a better life. So

exponentially increase in population demands more space. The older street patterns were causing congestion issues. The traffic problems are the biggest problem now a day in Quetta. So that is why the new areas which are developing would have different street patterns. Still a lot of improvement is needed. (Alamy.2018. Urban vector city map of Quetta, Pakistan & Alamy.2021.new era of development)

2.6.3 Ankara

Due to rapid growth and for improvement of physical environment and structure of city the 3 eras of development were observed in Ankara city. Firstly, due to space issues and environmental issues the radial pattern was changed into a rectangular pattern. After again the rapid growth the rectangular pattern was changed to curvilinear and web pattern. (Sorokin.I.2017.Ankara Turkey Map in retro style)

2.6.4 Khorramabad

Khorramabad had the environmental issues in the central part of it. So, the central street patterns were changed to warped parallel pattern and the issue was somehow resolved.. (KARIMI.K.2002. Iranian Organic Cities Demystified: A Unique Urban Experience or an Organic City like Others) (“Iranian Organic Cities Demystified: A Unique Urban Experience or an ...”)

2.7 Relation of Street Patterns with Sustainable Urban Planning

There is an extraordinarily strong link between street patterns and sustainability as when we are talking about sustainability, we are talking about economy, efficiency and environment protection. An efficient street pattern will have less dependence on fossil fuels as an efficient transportation system requires less vehicle trips which reduces the depletion of environment. An efficient street pattern also achieves economic sustainability. We reviewed existing street patterns in major cities of the world, and we got an idea about different street patterns such as rectilinear

grid pattern, curvilinear street pattern, the spider-web or star pattern, diamond pattern, stem pattern, the picturesque landscape pattern and warped parallel pattern. Rectilinear grid pattern is a type of city plan in which streets run at right angles to each other, forming a grid whereas curvilinear street pattern is characterized by streets with multiple curves, typical of many modern subdivisions (Dale & Sharn, 1996). The Spider-web or Star Pattern is a modified grid that provides fewer connections than the Rectilinear and Diamond Grid and more easily adapts to the terrain. (“6. Street Patterns.pdf - Urban Street Pattern ARCH 305:...”) Diamond pattern is a grid street system characterized by interconnections at angles "A series of cul-de-sac streets feeding onto collector streets and arterials characterize the stem pattern."." (“6.Street Patterns.pdf - Urban Street Pattern ARCH 305:...”) A loose and warped (partial) grid is called the picturesque landscape pattern. The warped parallel pattern comprises curvy *streets* in long, narrow blocks. T intersections and L corners. (Rifaat et al., 2016)

2.8 Water Supply systems used in different street patterns.

Grid iron system is used in rectilinear grid iron street pattern. Dead end or tree system is used in curvilinear street pattern while radial system is used in radial or star street pattern.

2.9 Different Water Supply Systems in different cities

New York City has a Grid iron water supply system. Denmark and Paris have Radial water supply system while of late 20th century suburbs of Calgary show Dead end or tree system. Two thirds of Chicago have a separate sewer system while the remaining one third has combined. Half of Philadelphia has been combined while remaining half has separate. Chandigarh city has Separate sewer system. (Philadelphia Water Department, n.d.) Combined sewer systems are more economical and thus grid iron pattern is more recommended.

2.10 Drainage

A typical drainage strategy usually defines:

- The site's characteristics (slope profile, soil geology, existing flood risk.
- The calculated surface water runoff rates and required storage volume.
- Where the runoff is to be discharged to
- The sustainable drainage system (SDS) features proposed.
- How the drainage system is going to be managed and maintained

An essential first step to the right design is to understand the ground drainage conditions and the site's suitability for infiltration. (David,2018). Another Major criterion while planning and designing the drainage infrastructure is climate change. Planning for storm drainage infrastructure is largely concerned with allocating land and obtaining easements to make room for it as well as preventing or minimizing interactions between drainage infrastructure and adjacent development. What level of service a particular drainage infrastructure should offer (i.e., what are the effects of flooding and how frequently is flooding acceptable?) determines the magnitude of this design flow, which is frequently defined in terms of recurrence frequency, either as a probability of flow exceedance or a recurrence interval between events of comparable magnitude. Once the level of service is selected and the appropriate design frequency is chosen, hydrotechnical design involves the use of accepted design methodologies, considering hydrologic input and appropriate design parameters.

The past performance of natural systems and the ability to extrapolate the performance of natural systems and engineered assets beyond the usable design life of the drainage infrastructure are traditionally the criteria considered when planning and developing the drainage

infrastructure. But if we consider the effect of climate change which will probably occur in the future and which may require more amount of water to be drained, designers and operators of storm drainage systems must prepare for grater uncertainty in the design of storm drainage systems. (Arisz.H & Burrell. C. B, 2006).

2.10.1 Drainage systems used in different street patterns.

There are various types of drainage systems such as Surface Drainage Systems, Subsurface Drainage Systems, Slope Drainage Systems, Downspouts and Gutter Systems, Swale Drains, Point Drains, French Drains, Trench Drains, HDPE Drains, Cast-In-Place Trench Drains. In spider web street pattern, separate sewer systems are used as it's used in undulating areas and separate sewer systems prevent the flooding of low-lying areas in slopy areas while in grid iron street pattern mostly separate sewer systems are used but in some areas combined systems are also used.

In spider web street pattern, separate sewer systems are used as it's used in undulating areas and separate sewer systems prevent the flooding of low-lying areas in slopy areas while in grid iron street pattern mostly separate sewer systems are used but in some areas combined systems are also used.

2.11 Best sewerage method:

As the curvilinear street pattern is most appropriate among all street patterns because of its efficiency and low cost.so for the curvilinear pattern the disposable method should be offsite

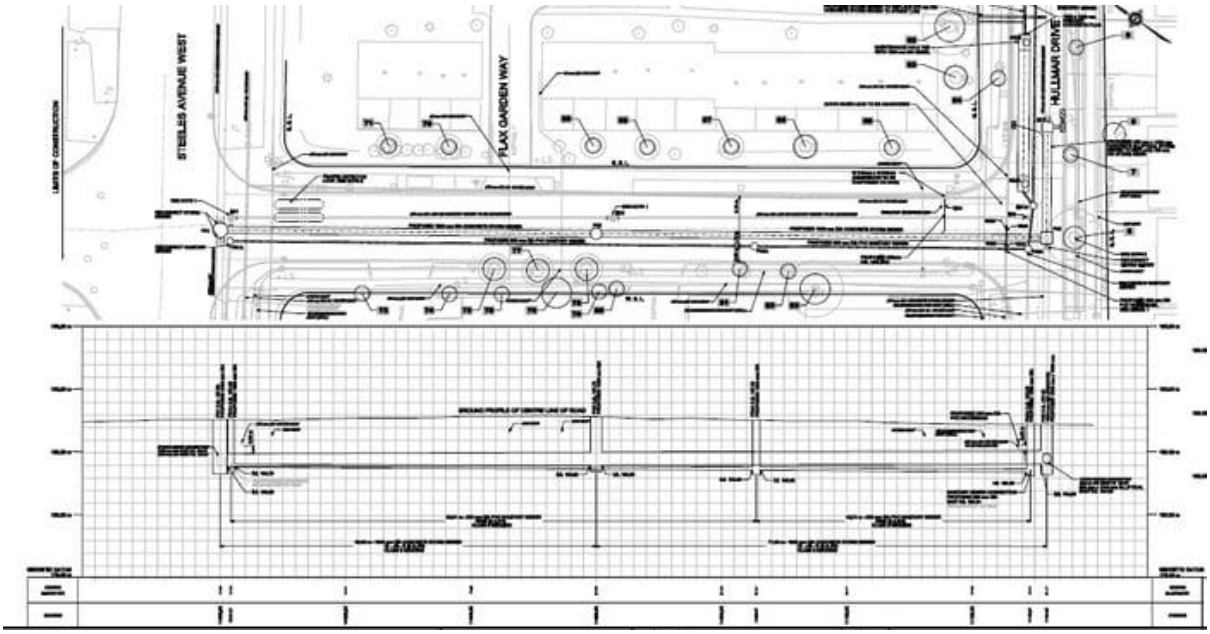


Figure 12 Typical sewerage layout

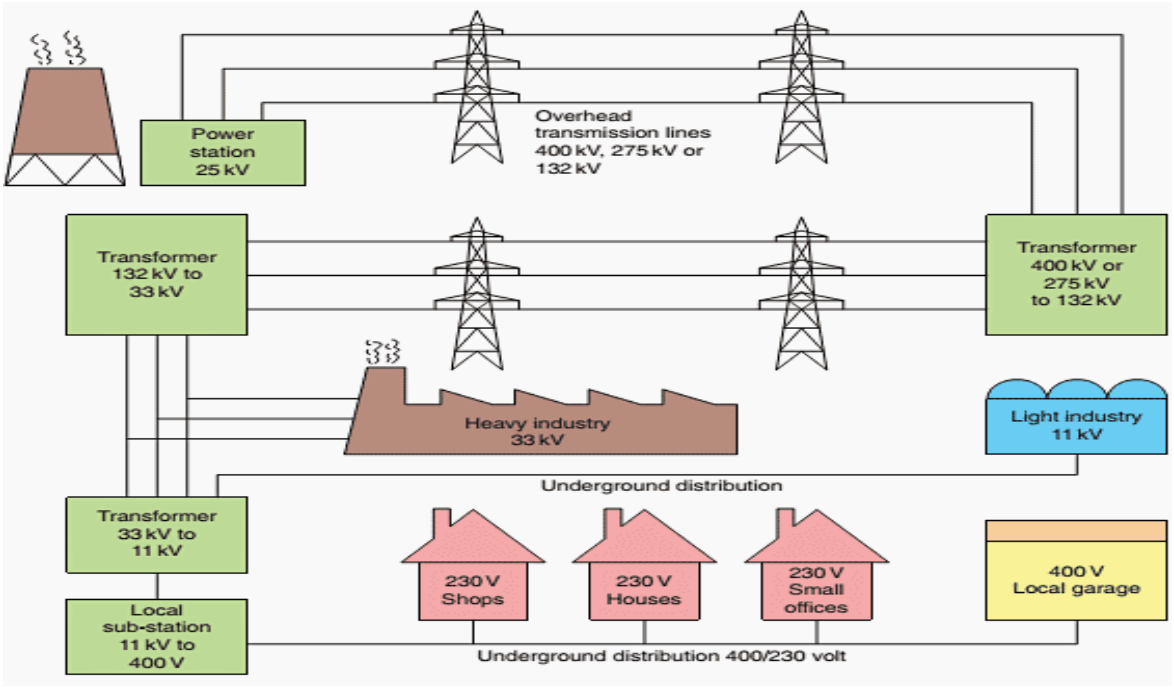


Figure13 electrical system layout

2.12.1 Best electrical system for an infrastructure

For the efficiency the most appropriate system is network system.it is more reliable but it is so expensive. The radial system is cheapest, but its reliability is so low. So, the loop system can be adopted for curvilinear street patterns. As its cost and efficiency both are maintained. And in case of power failure only one system is cutoff. other works in same manner. And the combination of these thrice network can also be used for better working sewerage system. As it can be installed underground and over surface both. And for sewage collection, if the population density is not so high so we will prefer combined sewerage system. It will be cheap as compared to separate system. but if the population density is so high so the large volume of water will reduce the efficiency of the combined system. So, then we will prefer the separate system. . Another limitation of this system is its lack of applicability to structures on soft soil. This is related to the properties of underlying soil on which the frequency of ground motion is dependent. In hard and stiff soils, the ground motion is rich with high frequency content while for soft soils, the ground motion consists of low frequencies. Base isolation works on the principle of elongating the period of a structure, hence making it more prone to resonance when used upon soft soils. Another conventional vibrational control mechanism involves employing the tuned mass damper. They are primarily designed for wind loading but have also been shown to be effective for seismic loading. As vibrations are induced in the structure, the TMDs on top of the structure move out of phase. As a result, energy is dissipated with resonant vibrations of the damper. However, their efficacy varies with the type of earthquake, being noticeably effective only for earthquakes with low to medium intensity, in which the response is mainly governed by the fundamental vibration mode of the structure they are installed in. With varying time and loading conditions, structures usually face variation in stiffness especially when they undergo elastoplastic behavior, which results in

detuning of the TMDs. Even when the TMDs are optimized for elastoplastic behavior, their performance decreases with increase in the structural response's hysteretic portion. Moreover, it has also been reported that the effectiveness of TMDs decreases as the PGA value goes up. For PGA values greater than 0.176, effectivity can be as low as 10%..

Chapter Three

Materials and methodology

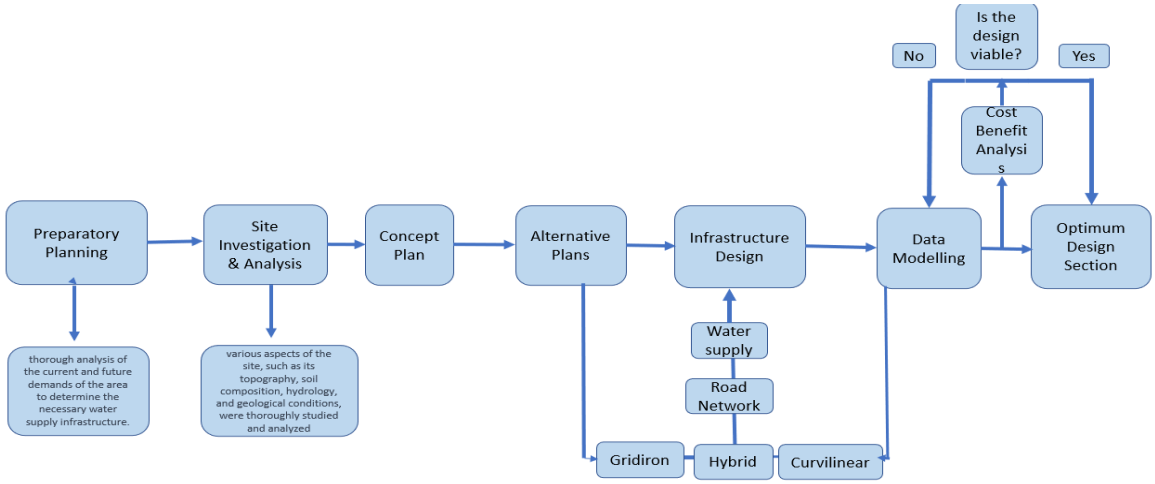


Figure 14: Methodology

3.1 Preparatory Planning

Thorough analysis of the current and future demands of the area to determine the necessary water supply infrastructure.

3.2 Site Investigation and Analysis

Various aspects of the site such as its topography, soil composition, hydrology, and geological conditions were thoroughly studied and analyzed.

3.3 Alternative Plans

Site investigation and analysis helped us in identifying the topographic features of the land such as the elevation of each point, and the existence of various land features such as water bodies etc. Site investigation helped us in the formation of various master plans of our site based on the site

characteristics. Three master plans based on hybrid street pattern (combination of radial + curvilinear pattern), curvilinear pattern and gridiron pattern.

3.3.1 Software

AutoCAD software developed by Autodesk was used for the development of master plans. The software incorporated various algorithms for the creation of precise 2D and 3D drawings and models, as well as electrical diagrams, construction drawings, and more. The source code for the software is available on Getintopc at [https://getintopc.com/softwares/3d-cad/autodesk-autocad-2024-free-download-4847261/]."

3.4 Infrastructure Design

Infrastructure Design that incorporated the development of road network and water design for each of the master plans was done.

3.4.1 Software

Watergems software developed by Bentley was used for water network design. The software incorporated various algorithms for the analysis, design, and optimization of our water distribution systems. The source code for the software is available on Getintopc at “Bentley OpenFlows Water GEMS CONNECT Edition 2022 Free Download (getintopc.com)]."

3.5 Cost Benefit Analysis

The cost of each of the design was calculated and compared.

3.5.1 Software

Microsoft Excel developed by Microsoft was used for cost analysis. . The software incorporated various algorithms for formatting, organizing and calculating data in a spreadsheet.

Chapter Four

Results and discussions

After making the plans for the Akbar town. The saleable area and efficiency have been determined. The number of houses for each type of pattern is calculated. The commercial, residential, institutional and all other areas are calculated and mostly kept same as original plan. widths and other dimensions of road are also kept same. The results are as follows.

4.1 Curvilinear

Table 3 : schedule of building of curvilinear

Sr no	Land use	Area(kanal)	Percentage %	Rec per%
1	Residential	254.46	54	55 to 57
2	Mixed use	27.5		
3	commercial	9.1	3.54	5
4	parking	5.3		
5	Community facility	14.01	3.62	2-10
6	Open space	24.8	7.07	7 (min)
7	Graveyard	7.6	2	2(min)
8	Walkways	2	0.57	--
9	Roads	124.59	35.50	--

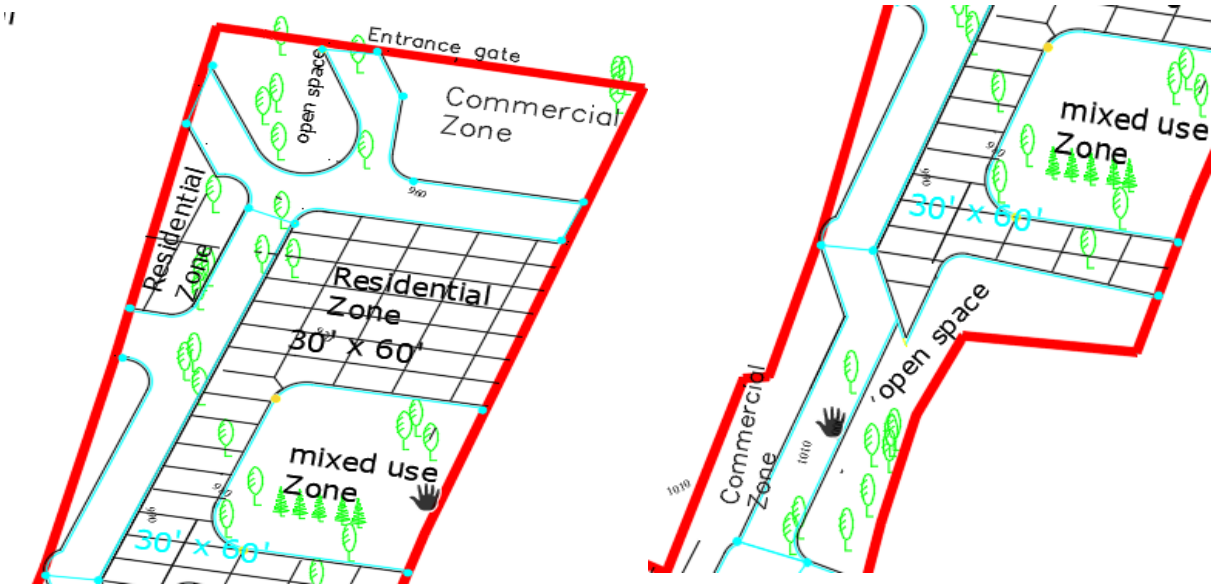


Figure 14 Types of houses in the curvilinear pattern of residential area:

Table 4 : schedule of plots residential of curvilinear Mostly the semidetached and detached type

SCHEDULE OF PLOTS RESIDENTIAL				
S.NO	Plot Size	No. of Plots	Area (Kanal)	Legend
1	MIX USE/APT.	05	24.5	
2	30' x 60'	135	44.62	
3	20' x 40'	1200	176.34	
4	TOTAL	1335	254.46	-

of houses are there. Which are suitable for the curvilinear type of the road pattern.

The types of plots (on area based) which are there are as follows.

30 x 60 = 135 plots detached 44. 64 kanals of area

20 x 40 = 1200 plots semidetached and detached covers 176. 3085 kanals of area

Single story houses: 912

Double story houses: 423

Society location and land use proportion:

This society is basically located in Attock Punjab. The bylaws for the attock Punjab are as follow:

Residential area: 55%

Commercial area: 5%

Industrial area: 8%

Community center: 2% to 10%

Graveyard:3%

All the calculations are under the maximum percentage.

Schedule of plots commercial:

Table 5 : schedule of plots commercial curvilinear

SCHEDULE OF PLOTS COMMERCIAL					
S.NO	Plot Size	Block	No. of Plots	Area (Kanal)	Legend
1	30' x 60'	A	11	3.99	
2	20' x 30'		04	0.44	
3	30' x 40'	B	04	0.88	
4	20' x 30'		18	1.98	
5	PARKING	-	-	5.19	
6	TOTAL	-	37	12.48	-

Table 6 : schedule of public building of curvilinear

SCHEDULE OF PUBLIC BUILDING			
Sr. No	LAND USE	BLOCK	AREA (Kanal)
1.	MASJID-01	A	2.26
2.	SCHOOL		4.07
3.	Community Centre		3.05
4.	S.W.M		0.61
5.	SOCIETY OFFICE		0.76
6.	S.T.P	B	1.99
	TOTAL AREA		12.74

4.2 Grid iron

Land use proportions

Table 7: schedule of land use of gridiron

SCHEDULE OF LANDUSE				
Sr. No	LAND USE	AREA (Kanal)	% AGE	REQ. % AGE
1.	Residential	135.72	38.58 %	55 (max)
2.	Commercial	12.21	3.47 %	5 (max)
3.	Institutional	39.65	11.26%	3% (min)
4.	Recreational	49.89	14.17%	7% (min)
5.	Graveyard	29.61	8.41%	2% (min)
6.	Road	139.15	39.54%	2% (min)
7.	Project Area	352.00	100%	100%

Residential Area

Number of plots

3 Marla Plots: 595

7 Marla Plots: 74

Total no. of plots: 669

Commercial Area

Schedule of plots commercial:

Table 8 : schedule of commercial plots of grid iron

SCHEDULE OF PLOTS COMMERCIAL

S.NO	Plot Size	Block	No. of Plots	Area (Kanal)	Legend
1	30' x 60'	A	11	3.99	
2	20' x 30'		04	0.44	
3	30' x 40'	B	04	0.88	
4	20' x 30'		18	1.98	
5	PARKING	-	-	5.19	
6	TOTAL	-	37	12.48	-

Total Area: 12.21 kanal (3.47%)

4.2.1 Location of commercial area

In the grid iron pattern master plan of the selected site (Akbar Town), there are a total of 4 commercial zones, each separated by a road, or some other zone between them. 2 commercial zones exist right after the entrance, and both are separated by a main road between them.

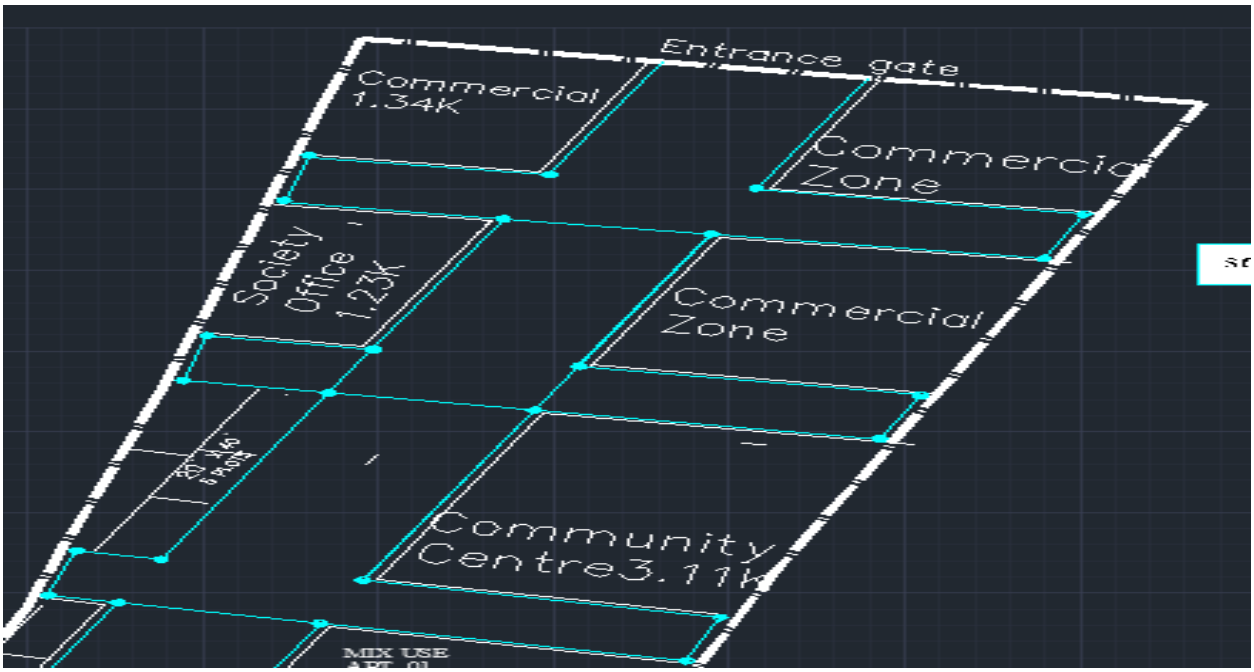


Figure 25: Location of commercial area in grid iron pattern

These 2 zones are placed near the entrance as the entrance gate of the housing society i.e., Akbar Town is located on National Highway. Commercial zones require direct transport networks to make the process of transportation of goods to and from the commercial zones easy, effective and fast.

Furthermore, there is another major concern when allocating commercial zones i.e., the commercial zone shouldn't be located near to residential zone. This concern is also kept in mind while selecting the location of these 2 commercial zones due to which society office and another commercial zone is provided adjacent to the first two commercial zones.

For third commercial zone also the above 2 criteria are kept in mind because of which society office and community center are placed adjacent to the commercial zone. For the fourth commercial zone also the concern of keeping residential and commercial zones separate is considered due to which the commercial zone is placed adjacent to the S.T.P., Bank, School and Masjid.

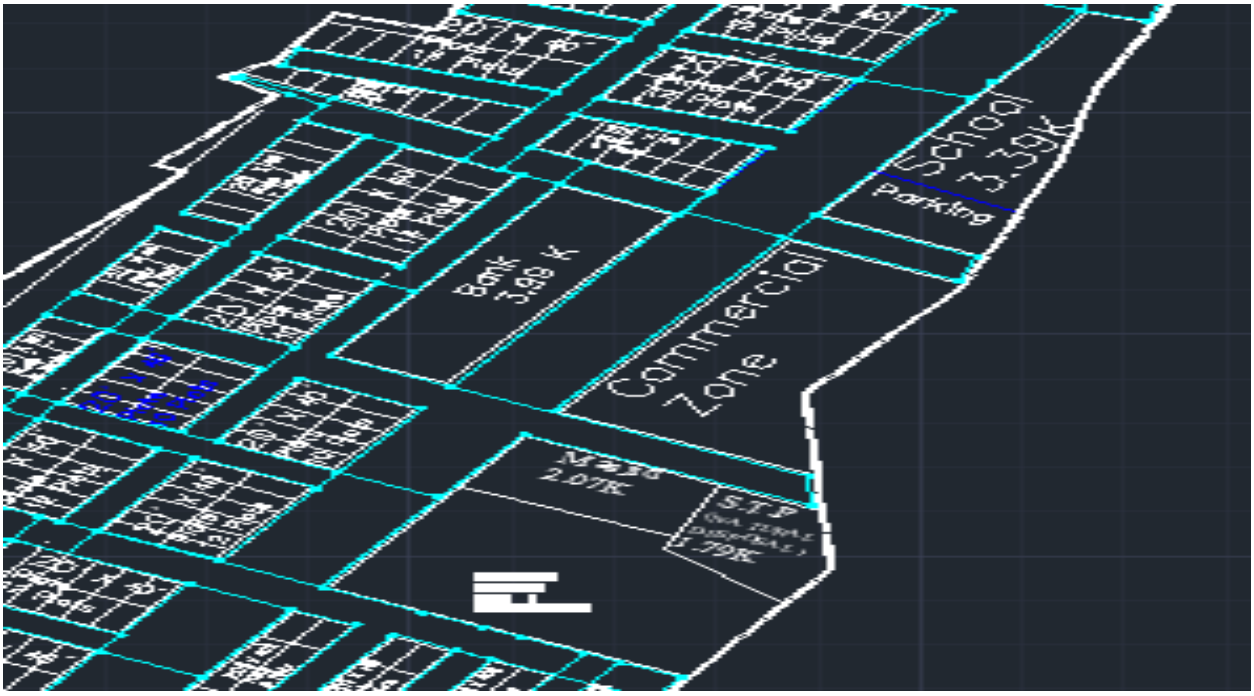


Figure 16: Location of commercial area

4.2.2 Graveyard

4.2.2.1 Area

Total Area: 29.61 kanal (8.41%)

The minimum area required to be allocated for graveyard is 2% according to Punjab guidelines for a private housing scheme. We followed the guidelines of Punjab government for private housing scheme and provided this much area for graveyard.

4.2.2.2 Location

Graveyard is provided near the main road in this masterplan as funeral processions and visits from family and friends should be able to readily enter the cemetery. It should be situated in a place with convenient transit options, such close to a major road.

4.2.3 Schedule of public buildings

Table 9 : schedule of public building of Gridiron

SCHEDULE OF PUBLIC BUILDING			
Sr. No	LAND USE	BLOCK	AREA (Kanal)
1.	MASJID-01	A	2.26
2.	SCHOOL		4.07
3.	Community Centre		3.05
4.	S.W.M		0.61
5.	SOCIETY OFFICE		0.76
6.	S.T.P	B	1.99
	TOTAL AREA		12.74

For curvilinear:

Table 10: schedule of building of Hybrid

Sr no	Land use	Area(kanal)	Percentage %	Rec per%
1	Residential	155.82	47.80	55 to 57
2	Mixed use	27.5		
3	commercial	9.1	3.54	5
4	parking	5.3		
5	Community facility	14.01	3.62	2-10
6	Open space	24.8	7.07	7 (min)
7	Graveyard	7.6	2	2(min)
8	Walkways	2	0.57	--
9	Roads	124.59	35.50	--
10	Projected area	352	100	100

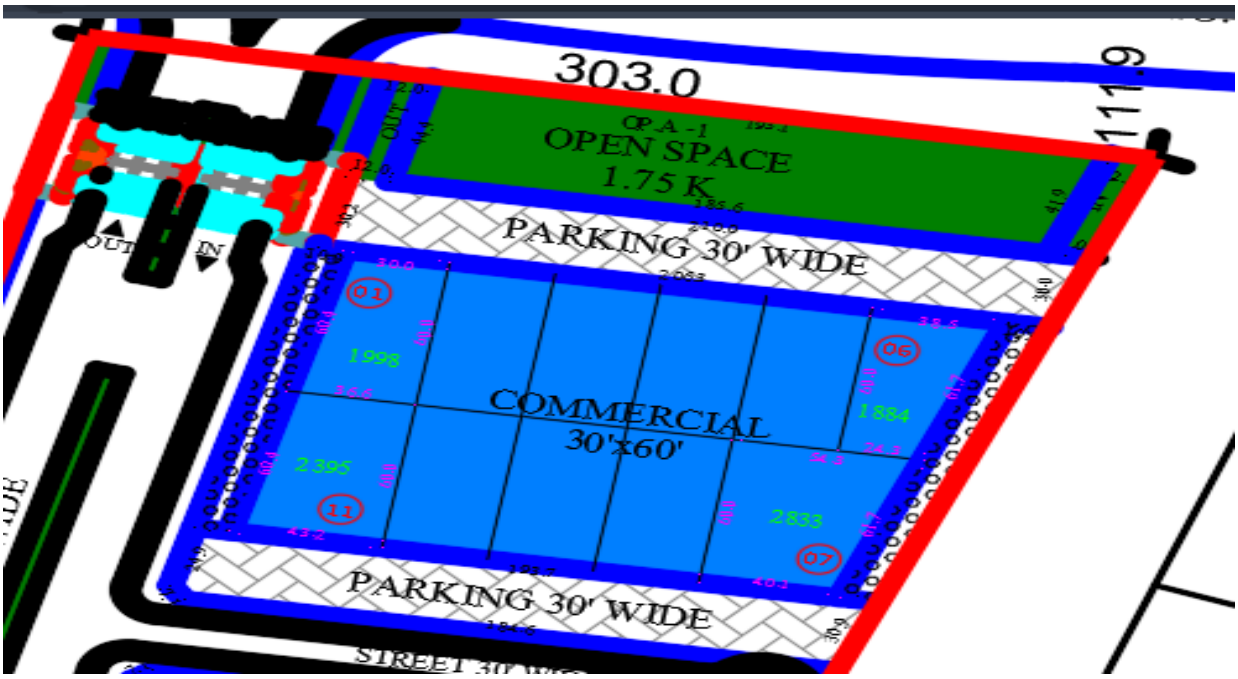


Figure 17 pictures from original drawings mostly commercial open space and residential area

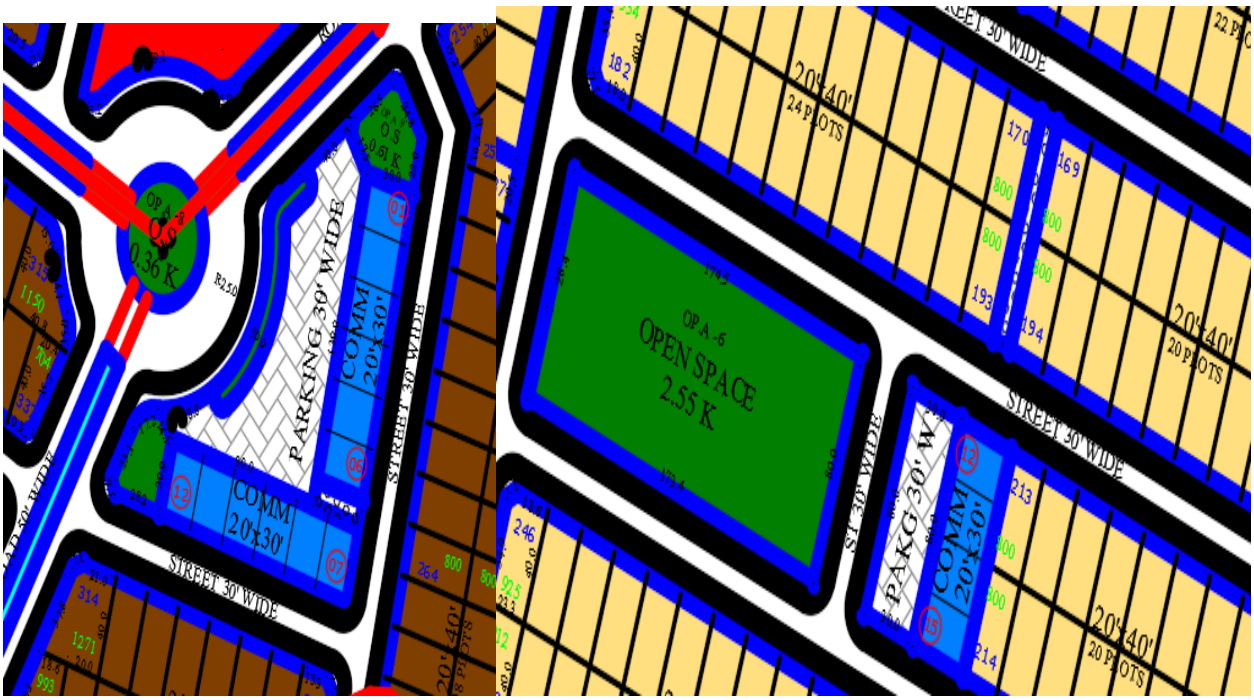


Figure 18: picture of public buildings of hybrid pattern

Schedule of plots commercial:

Table 11 : schedule of commercial building of Hybrid pattern

SCHEDULE OF PLOTS COMMERCIAL					
S.NO	Plot Size	Block	No. of Plots	Area (Kanal)	Legend
1	30' x 60'	A	11	3.99	
2	20' x 30'		04	0.44	
3	30' x 40'	B	04	0.88	
4	20' x 30'		18	1.98	
5	PARKING	-	-	5.19	
6	TOTAL	-	37	12.48	-

Schedule of Residential Plots

Table 12 : schedule of residential building of Hybrid pattern

SCHEDULE OF RESIDENTIAL HOUSING UNITS (GROUND +01)					
S.NO	Plot Size	Block	No. of Houses	Area (Kanal)	Legend
1	30' x 60'	A	18	6.22	
2	20' x 40'		467	70.01	
3	20' x 40'	B	457	68.89	
4	TOTAL	-	942	145.12	-

Schedule of public buildings

Table 13: schedule of public building of Hybrid pattern

SCHEDULE OF PUBLIC BUILDING			
Sr. No	LAND USE	BLOCK	AREA (Kanal)
1.	MASJID-01	A	2.26
2.	SCHOOL		4.07
3.	Community Centre		3.05
4.	S.W.M		0.61
5.	SOCIETY OFFICE		0.76
6.	S.T.P	B	1.99
	TOTAL AREA		12.74

4.3 WATER SUPPLY CALCULATIONS AND RESULTS

4.3.1 Grid iron pattern

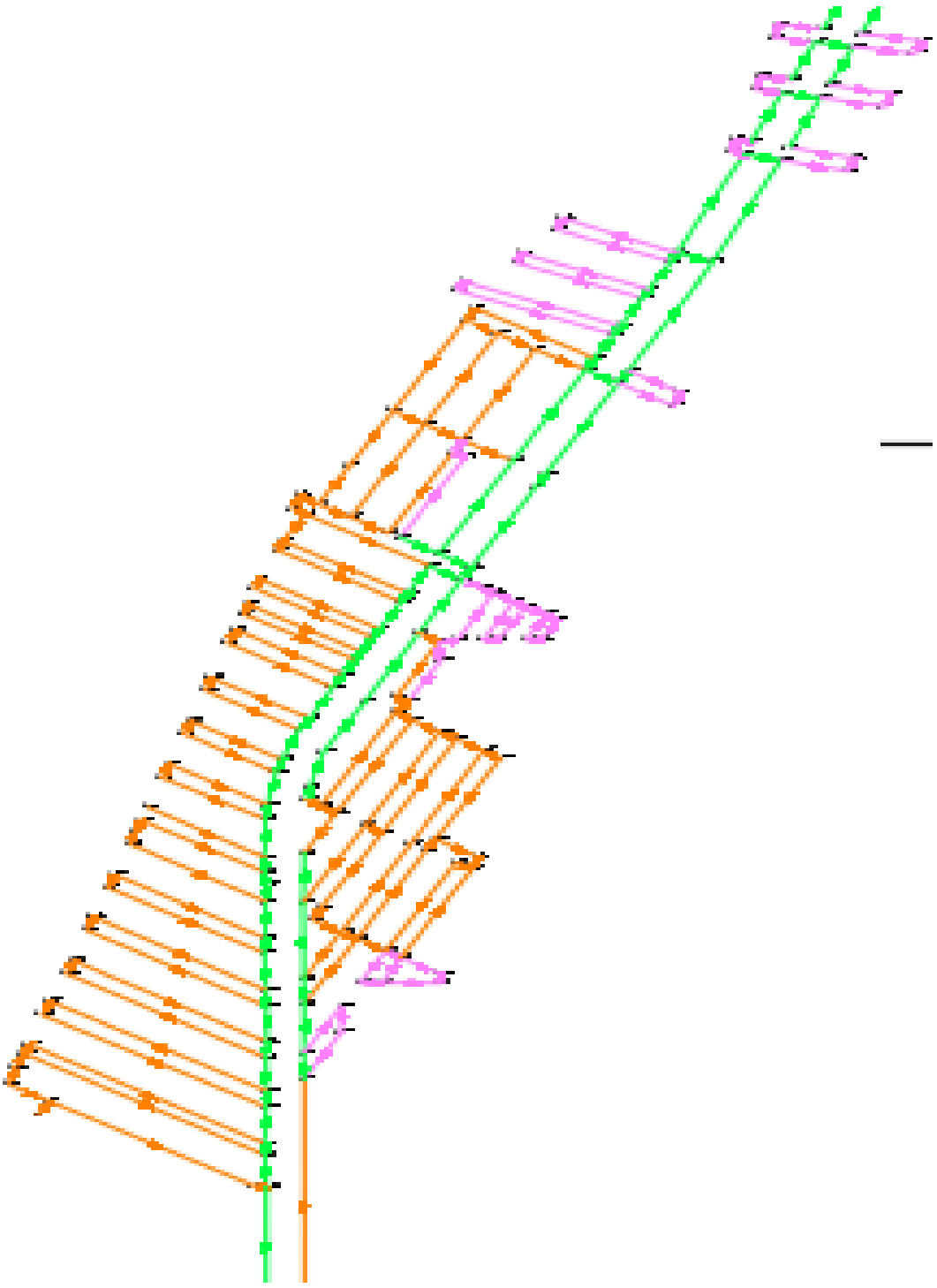


Figure 19: Water network of grid iron pattern

Table 12: Water Demand Calculations for Grid iron Pattern

Akbar town Grid iron

WATER DEMAND CALCULATIONS

	CRITERIA FOLLOWED				PHED/WASA/BAHRIA TOWN				
	RESIDENTIAL DEMAND		(PLOTS)						
1	PLOT DETAIL			POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPD)	
	SIZE		NO. OF PLOTS						
	3	Marla	595	7	4165	50	189	208250	
	7	mrla	74	7	518	50	189	25900	
	TOTAL		669		4683			234150	
2	RESIDENTIAL DEMAND		(APARTMENTS)						
	SIZE		NO. OF APTS	POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPCD)	
	MIXED USE		121	7	847	50	189	42350	
	OTHERS		0	0	0		0	0	
	TOTAL		121		847			42350	
	TOTAL POPULATION		(PLOTS + APARTMENTS)		5530				PERSONS
A	RESIDENTIAL DEMAND		(PLOTS + APARTMENTS)		276500				GPD
B	Mosque (for 20% pop @ 3 gpcd)			1No.	1106	Persons		3318	GPD
C	Offices (Pop @ 15gpcd)			1	10	Persons		150	GPD
D	Hospital (per bed @ 10gpcd)			0No	0	Persons		0	GPD
E	Educational Institutions (15% @8 gpcd)			1No	830	Persons		6636	GPD
F	Commercial Area (0.20 gallons/sft)				66483	Area in Sft		13297	GPD
G	Parks + Green Areas (@5 gallons/100 sft)				271651	Area in Sft		13583	GPD
H	Daily Demand (Qd.)							313483	GPD
I	Non Revenue Water (NRW) @10% of Qd.							31348	GPD
J	Fire Demand (@ 10% of Qd.)							31348	GPD
K	Average Daily Demand (Q avg.)			Qd + NRW + Fire Demand				376180	GPD
L	Maximum Daily Demand (Q max.)			Qavg. X 1.5				564270	GPD
M	Peak Hourly Demand (Q peak)			Qmax. X 1.5				846405	GPD
	TUBE WELL REQUIREMENTS								
N	Average discharge of Tube well (hourly)							13450	GPH
O	Average discharge of Tube well (daily)							215200	GPD
	No of Tube Wells Req.							3	No.
	STORAGE REQUIREMENTS								
P	Req. Storage Capacity			50% of Q avg.				188090	GPD
Q	No of Over Head Tanks (OHT)			100,000 GALLONS				1	No.
R	No of Over Head Tanks (OHT)			200,000 GALLONS				0	No.
S	No. of Under Ground Tanks (UGWT)			200,000 GALLONS				1	No.

Table 13: Water Demand Calculations for Curvilinear Pattern

AKBAR TOWN ATTOCK									
WATER DEMAND CALCULATIONS FOR CURVILINEAR PATTERN OF AKBAR TOWN									
CRITERIA FOLLOWED					**PHED/WASA/BAHRIA TOWN**				
	RESIDENTIAL DEMAND		**(PLOTS)**						
1	**PLOT DETAIL**			**POPULATION EQUIVALENT (PE)**	**POPULATION**	**PER CAPITA CONSUMPTION (GPCD)**	**PER CAPITA CONSUMPTION (LPCD)**	**DEMAND (GPD)**	
	SIZE		**NO. OF PLOTS**						
	3	**Marla**	1200	7	8400	**50**	189	420000	
	7	**marla**	135	7	945	**50**	189	47250	
	TOTAL		**1335**		**9345**			**467250**	
2	**RESIDENTIAL DEMAND**		**(APARTMENTS)**						
	SIZE		**NO. OF APTS**	**POPULATION EQUIVALENT (PE)**	**POPULATION**	**PER CAPITA CONSUMPTION (GPCD)**	**PER CAPITA CONSUMPTION (LPCD)**	**DEMAND (GPCD)**	
	MIXED USE		0	7	0	50	189	0	
	OTHERS		0	0	0		0	0	
	TOTAL		**0**		**0**			**0**	
	TOTAL POPULATION		**(PLOTS + APARTMENTS)**		**9345**				**PERSONS**
A	**RESIDENTIAL DEMAND**		**(PLOTS + APARTMENTS)**		**46725 0**				**GPD**
B	**Mosque (for 20% pop @ 3 gpcd)**			2 No.	1869	Persons		5607	GPD
C	**Offices (Pop @ 15gpcd)**			65	650	Persons		9750	GPD
D	**Hospital (per bed @ 10gpcd)**			0 No.	0	Persons		0	GPD
E	**Educational Institutions (15% @8 gpcd)**			4 No.	1402	Persons		11214	GPD
F	**Commercial Area (0.20 gallons/sft)**				67082	Area in Sft		13416	GPD
G	**Parks + Green Areas (@5 gallons/100 sft)**				271651	Area in Sft		13583	GPD
H	**Daily Demand (Qd.)**							**520820**	GPD
I	**Non Revenue Water (NRW) @10% of Qd.**							52082	GPD
J	**Fire Demand (@ 10% of Qd.)**							52082	GPD
K	**Average Daily Demand (Q avg.)**			**Qd + NRW + Fire Demand**				**624984**	GPD
L	**Maximum Daily Demand (Q max.)**			**Qavg. X 1.5**				937476	GPD
M	**Peak Hourly Demand (Q peak)**			**Qmax. X 1.5**				140621 4	GPD
	TUBE WELL REQUIREMENTS								
N	**Average discharge of Tube well (hourly)**							13450	GPH
O	**Average discharge of Tube well (daily)**							215200	GPD
	No of Tube Wells Req.							4	No.
	STORAGE REQUIREMENTS								
P	**Req. Storage Capacity**			**50% of Q avg.**				312492	GPD
Q	**No of Over Head Tanks (OHT)**			100,000 GALLONS				**1**	**No.**
R	**No of Over Head Tanks (OHT)**			200,000 GALLONS				0	No.

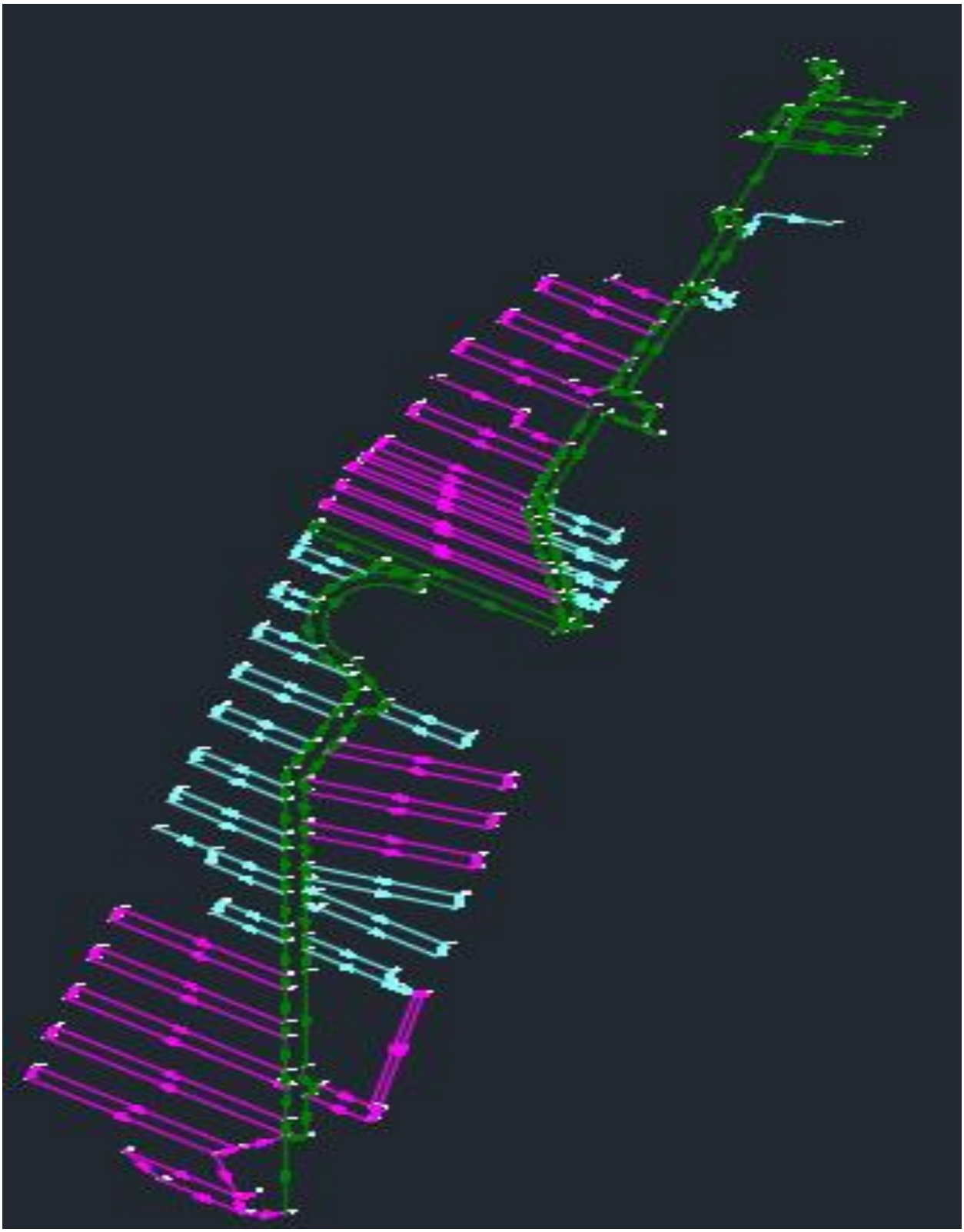


Figure 20: Water Network of Curvilinear Pattern

Table 14 : Water demand calculations of residential building of curvilinear pattern

AKBAR TOWN ATTOCK									
WATER DEMAND CALCULATIONS FOR CURVILINEAR PATTERN OF AKBAR TOWN									
CRITERIA FOLLOWED					PHED/WASA/BAHRIA TOWN				
	RESIDENTIAL DEMAND		(PLOTS)						
1	PLOT DETAIL			POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPD)	
	SIZE		NO. OF PLOTS						
	3	Marla	1200	7	8400	50	189	420000	
	7	marla	135	7	945	50	189	47250	
	TOTAL		1335		9345			467250	
2	RESIDENTIAL DEMAND		(APARTMENTS)						
	SIZE		NO. OF APTS	POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPCD)	
	MIXED USE		0	7	0	50	189	0	
	OTHERS		0	0	0		0	0	
	TOTAL		0		0			0	
	TOTAL POPULATION		(PLOTS + APARTMENTS)		9345				PERSONS
A	RESIDENTIAL DEMAND		(PLOTS + APARTMENTS)		46725 0				GPD
C	Offices (Pop @ 15gpcd)			65	650	Persons		9750	GPD
D	Hospital (per bed @ 10gpcd)			0 No.	0	Persons		0	GPD
E	Educational Institutions (15% @8 gpcd)			4 No.	1402	Persons		11214	GPD
F	Commercial Area (0.20 gallons/sft)				67082	Area in Sft		13416	GPD
G	Parks + Green Areas (@5 gallons/100 sft)				271651	Area in Sft		13583	GPD
H	Daily Demand (Qd.)							520820	GPD
I	Non Revenue Water (NRW) @10% of Qd.							52082	GPD
J	Fire Demand (@ 10% of Qd.)							52082	GPD
K	Average Daily Demand (Q avg.)			Qd + NRW + Fire Demand				624984	GPD
L	Maximum Daily Demand (Q max.)			Qavg. X 1.5				937476	GPD
M	Peak Hourly Demand (Q peak)			Qmax. X 1.5				1406214	GPD
	TUBE WELL REQUIREMENTS								
N	Average discharge of Tube well (hourly)							13450	GPH
O	Average discharge of Tube well (daily)							215200	GPD
	No of Tube Wells Req.							4	No.
	STORAGE REQUIREMENTS								
P	Req. Storage Capacity			50% of Q avg.				312492	GPD
Q	No of Over Head Tanks (OHT)			100,000 GALLONS				1	No.
R	No of Over Head Tanks (OHT)			200,000 GALLONS				0	No.
S	No. of Under Ground Tanks (UGWT)			200,000 GALLONS				1	No.

4.3.3 HYBRID pattern: Water Supply Model and Demand Calculations

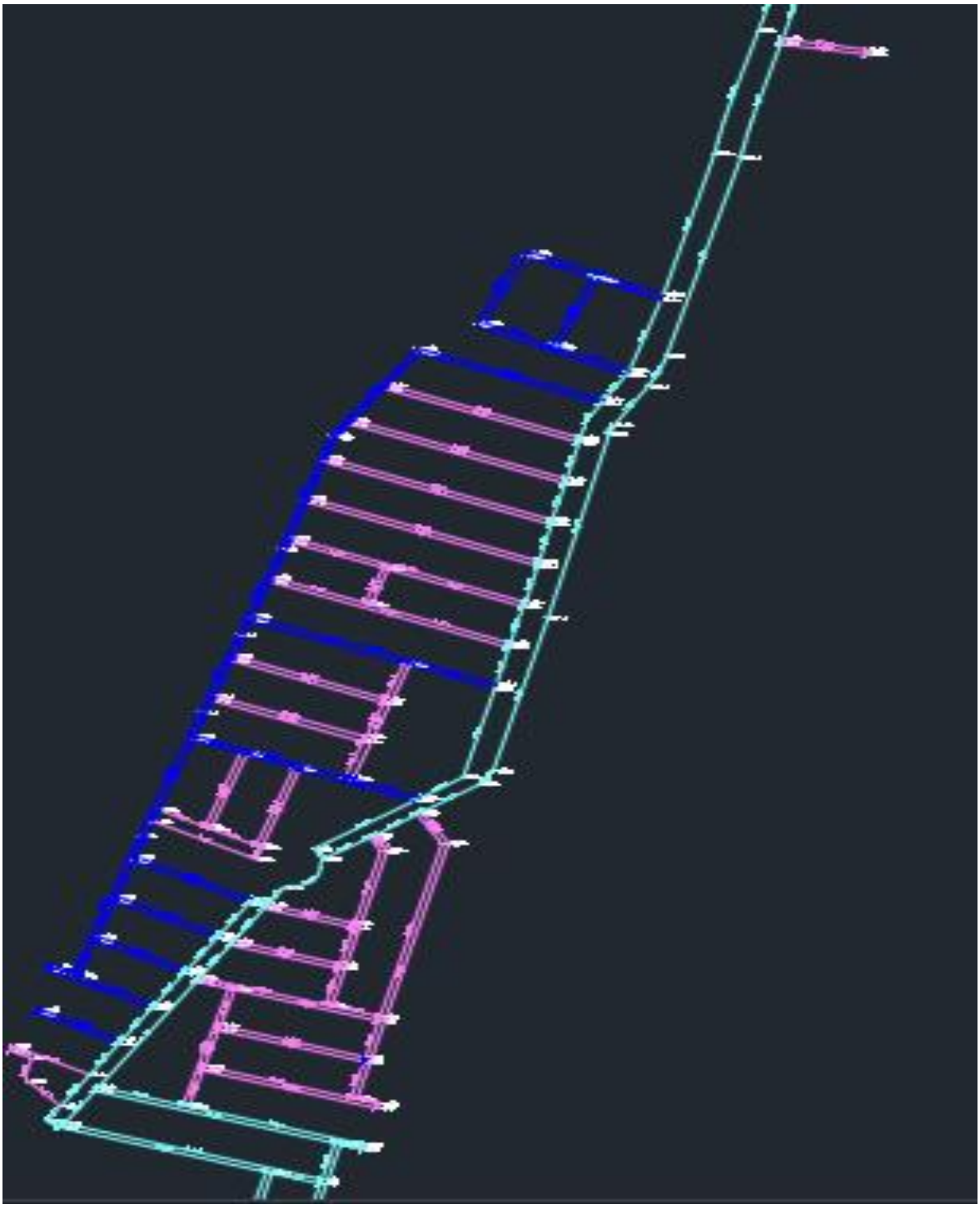


Figure 21: Water Network for Curvilinear Pattern

Table 15: Water demand calculations of residential building of Hybrid pattern

AKBAR TOWN ATTOCK									
WATER DEMAND CALCULATIONS									
CRITERIA FOLLOWED					PHED/WASA/BAHRIA TOWN				
1	PLOT DETAIL			POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPD)	
	SIZE		NO. OF PLOTS						
	3	Marla	924	7	6468	50	189	323400	
	7	marla	18	7	126	50	189	6300	
	TOTAL		942		6594			329700	
2	RESIDENTIAL DEMAND		(APARTMENTS)						
	SIZE		NO. OF APTS	POPULATION EQUIVALENT (PE)	POPULATION	PER CAPITA CONSUMPTION (GPCD)	PER CAPITA CONSUMPTION (LPCD)	DEMAND (GPCD)	
	MIXED USE		22	7	154	50	189	7700	
	OTHERS		0	0	0		0	0	
	TOTAL		22		154			7700	
	TOTAL POPULATION		(PLOTS + APARTMENTS)		6748				PERSONS
A	RESIDENTIAL DEMAND		(PLOTS + APARTMENTS)		33740 0				GPD
B	Mosque (for 20% pop @ 3 gpcd)			1 No.	1350	Persons		4049	GPD
C	Offices (Pop @ 15gpcd)			1	10	Persons		150	GPD
D	Hospital (per bed @ 10gpcd)			0 No.	0	Persons		0	GPD
E	Educational Institutions (15% @8 gpcd)			1 No.	1012	Persons		8098	GPD
F	Commercial Area (0.20 gallons/sft)				67891	Area in Sft		13578	GPD
G	Parks + Green Areas (@5 gallons/100 sft)				184803	Area in Sft		9240	GPD
H	Daily Demand (Qd.)							372515	GPD
I	Non Revenue Water (NRW) @10% of Qd.							37251	GPD
J	Fire Demand (@ 10% of Qd.)							37251	GPD
K	Average Daily Demand (Q avg.)			Qd + NRW + Fire Demand				447018	GPD
L	Maximum Daily Demand (Q max.)			Qavg. X 1.5				670527	GPD
M	Peak Hourly Demand (Q peak)			Qmax. X 1.5				100579 0	GPD
	TUBE WELL REQUIREMENTS								
N	Average discharge of Tube well (hourly)							13450	GPH
O	Average discharge of Tube well (daily)							215200	GPD
	No of Tube Wells Req.							3	No.
	STORAGE REQUIREMENTS								
P	Req. Storage Capacity			50% of Q avg.				223509	GPD
Q	No of Over Head Tanks (OHT)			100,000 GALLONS				1	No.
R	No of Over Head Tanks (OHT)			200,000 GALLONS				0	No.
S	No. of Under Ground Tanks (UGWT)			200,000 GALLONS				1	No.

4.5 Computational Results

4.5.1 Saleable area Comparison

FOR GRID IRON:

38.56%

AREA: 135.72 KANAL

FOR HYBRID PATTERN:

47.80%

AREA: 155.82 KANAL

FOR CURVILINEAR PATTERN:

54%

AREA:

182.46 KANAL

4.6 COST COMPARISON

Street Pattern	**Gridiron**	**Hybrid**	**Curvilinear**
Cost	217 million	270 Million	201.12 Million

Chapter Five

Conclusion

From The results the curvilinear pattern has proved to be the most efficient and cost effective and ecofriendly for the hilly type of terrain, here are the some more reason for its adaptation.

5.1 Why to Adopt Curvilinear Pattern For This Particular Site Of Akbar Town (Hilly Terrain)

As this pattern can be adapted to any type of topography, here in this site the mainly topography has different elevation throughout so that's why the curvilinear pattern is suitable for this type of topography. For a site with various elevations and oil fields, adapting a curvilinear road pattern has several benefits over using a linear road pattern. Here are a few explanations:

Increased Safety: By slowing down traffic and making it simpler to maneuver around obstacles or elevation changes, a curvilinear road pattern can increase site safety. This can lessen the chance of mishaps and injuries, which is crucial when working on oil or other potentially dangerous materials.

Effective Use of Space: A curvilinear road layout can also aid in making the best use of the site's available space. The roads can be made to avoid areas with steep slopes or other obstacles by following the contours of the land. In order to make construction easier, areas with steep slopes or other obstacles can be avoided when designing the roads. This may lessen the amount of grading and earthwork needed, saving time and money. A curvilinear road layout can also improve the site's aesthetic appeal. The environment can be made more aesthetically pleasing and harmonious by the roads' natural curves and flowing lines that can blend in more seamlessly with the surrounding landscape.

Reduced Environmental Impact: A curving road layout can also lessen the site's negative effects on the environment. The roads can be planned to cause the least amount of environmental disruption by avoiding sensitive habitats and other environmentally sensitive areas. Access to Oil Fields: A curvilinear road system can finally provide improved access to the actual oil fields. The roads can be made to provide safe and effective access to the oil fields, even in difficult terrain, by following the contours of the land and avoiding steep slopes. This can increase productivity and lower the chance of mishaps or injuries when entering the oil fields.

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